Now, where was I?
Examining the Perceptual Processes while Resuming an Interrupted Task

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Abstract

Several empirical papers have demonstrated that interruptions are disruptive and that after being interrupted it takes some time to resume the primary task. This study examined the cognitive processes, specifically at the perceptual level, that were used to resume a task after being interrupted. Eye movement data showed that participants were able to use spatial memory to return to the general area where they were interrupted. This spatial heuristic was used for interruptions that occurred both early and late in the primary task, however, participants were more imprecise when returning to the task after a late interruption.

Introduction

There is a great deal of evidence suggesting that in most instances interruptions are disruptive. Several empirical studies have demonstrated how detrimental an interruption can be to primary task performance (Altmann & Trafton, 2004; Monk, Boehm-Davis, & Trafton, 2004; Trafton, Altmann, Brock, & Mintz, 2003). Being interrupted can result in more errors on the primary task, a longer time to complete the primary task and greater feelings of stress and anxiety when performing the task (Adamcyzk & Bailey, 2004;Speier, Vessey, & Valacich, 2003).

One dependent measure that has been used to examine how disruptive an interruption can be is the *resumption lag* (Altmann & Trafton, 2004; Trafton et al., 2003). The resumption lag has been operationally defined as the time interval between the completion of the secondary (interrupting) task and the first action back on the primary task. The resumption lag is essentially the time it takes to resume the primary task after completing the interrupting task. For example, while working on a paper (the primary task) a student may stop by (interrupting task) to talk about research ideas. Once the student leaves, the time it takes to focus one's thoughts back on the paper and actually resume writing the paper is the resumption lag. How does one go about resuming the primary task after being interrupted?

Several studies have illustrated a significantly longer resumption lag after being interrupted as compared to a control condition (Altmann & Trafton, 2004; Monk et al., 2004; Trafton et al., 2003). However, most of the research on interruptions has dealt with reducing or changing the resumption lag, not on the processes used to resume the primary task. Several general memory theories have been applied to interruptions (e.g., Long Term Working Memory, (Ericsson & Kintsch, 1995; Oulasvirta & Sarrlilouma, 2004), however, these theories do not make clear predictions about the specific processes used to resume an interrupted task.

Altmann and Trafton (2002) have put forward an activation based memory model specific to the resumption of an interrupted task. This theory, called Memory for Goals, suggests that an interrupting secondary task results in a suspension of the current subgoal of the primary task. The resumption lag is a consequence of the time it takes to retrieve the suspended subgoal after completing the interrupting task. The most active goal is the goal that will be retrieved and the goal that will be selected to drive behavior. The theory suggests there are two determinants of goal activation, and consequently, two determinants of what goal will be retrieved when resuming the primary task. First, the activation of a goal is based on its history; for example how frequently the goal has been retrieved and how recently the goal was retrieved will impact goal activation. In addition, the activation is based on context and the environment. The context provides priming of the suspended goal resulting in a boost in its activation.

Several things should be noted about this description. First, the theory does not make any specific predictions about the perceptual processes used or needed to resume the primary task. Different environmental cues have been shown to facilitate resumption lag (Trafton, Altmann, & Brock, 2005), but the interaction between perceptual processes and environmental cues is currently unspecified. Second, the memory for goals theory (and others) make the assumption that resuming a task is, in large part, a matter of determining **what** had been done previously. For many tasks (e.g., computer based interactions), however, determining **where** in the task or interface pre-interruption work had occurred is just as important as determining what had been done previously.

The purpose of this paper is to examine the specific perceptual processes involved in resuming the primary task during the resumption lag. In order to examine the perceptual processes during the resumption lag a spreadsheet task was selected that had a flat goal structure. This flat goal structure allowed us to focus on where the resumption point should be rather than on what had been

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14. ABSTRACT
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one previously (though of course both are important in many computer-based tasks).

How do people determine where they were last working after being interrupted? After completing the interrupting task, one possibility is that during the resumption lag, the user could simply retrace their steps from the beginning of the task. Essentially, one could restart the task after being interrupted (Miller, 2002). Some empirical studies have shown that interruptions that occur early in the primary task are less disruptive than interruptions that occur in the middle of the primary task (Czerwinski, Cutrell, & Horovitz, 2000; Monk, Boehm-Davis, & Trafton, 2002). This finding can be explained by the retrace hypothesis by assuming that participants must restart some tasks, so being interrupted earlier is better because less work will have occurred.

A second possibility is that participants may use some type of environmental cue to resume the primary task (Trafton et al., 2005). In the current task, there was an environmental cue that could facilitate resumption (described below); thus at the perceptual level attention should be directed towards this cue.

A third possibility is that some type of spatial heuristic is used to recall the general area in the task where one left off, especially if the interruption is relatively brief. People may not recall specifically where to resume; however, the general area in the task where they were interrupted may be recalled. Thus, people may have some type of spatial memory for where to resume. Upon returning to the general area during the resumption lag one may retrace their steps to get to the specific point where they left off. The ability to remember general spatial information has also been observed in several visual search tasks and other computer tasks (Ehret, 2002).

By using an eye tracker, the study presented here examined the specific perceptual processes during the resumption lag. The goal was to determine where in the task participants resumed and how participants went about resuming the primary task during the resumption lag.

Experiment

In order to investigate the perceptual processes during the resumption lag, eye track data were collected as participants worked on a spreadsheet as the primary task and received instant messages as interruptions. The primary task required participants to search a column of numbers and to transcribe only the odd numbers onto a separate list. In order to examine whether different processes were used to resume the task depending on interruption point, interruptions occurred both early and late in the primary task. Participants received two interruptions in each interruptions trial, one in the first half of the primary task and one in the second half; the instant messages asked participants to take the sum of five numbers. The accumulating list of transcribed numbers served as a subtle cue to participants.

If participants retrace their steps from the beginning of the task after being interrupted, there are several straightforward predictions. The resumption lag for the early interruption should be shorter than the resumption lag for the late interruption. In the case of the early interruption, participants should return to the point where they left off fairly quickly. However, in the late interruption case it should take participants longer to reach the point where they left off due to increased search.

In terms of the eye movements, there should be fewer fixations during the resumption lag in the early interruption case as compared to the late interruption case. In the early interruption case, the point where participants should resume from is closer to the beginning of the task as compared to the late interruption case. Thus, if participants retrace their steps from the beginning, in the early interruption case, participants should reach the point where they need to resume in fewer fixations. Finally, if participants start from the beginning of the task after the interruption, their initial fixation location during the resumption lag should be the same. For both early and late interruptions, the initial fixation during the resumption lag should be to the beginning of the task.

If participants are using the environmental cue this should be reflected in the eye movements as well. Participants should resume the primary task at the location of cue. The initial fixation back to the column of numbers that is to be transcribed should be the same as the location of the cue. In addition, the initial fixation during the resumption lag for both early and late interruptions should be to different locations since the cues are in different locations, whereas if participants were starting the task over these fixations would be to the same location.

If participants use some kind of spatial heuristic to facilitate resumption during the resumption lag the initial fixation location should be different for early and late interruptions as well. The fixations should be in the general area where the interruption occurred. More importantly, if participants use a spatial heuristic, the initial fixation locations should not be the same as the location of the cues.

The resumption lag times were first examined to determine how disruptive the early and late interruptions were. The eye track data were then analyzed to examine what perceptual processes were used to resume the primary task.

Method

Participants. Eleven George Mason University students participated for course credit. A prerequisite of the experiment was that participants had to be familiar with the numeric keypad such that they did not have to look at the keys when entering numbers.

Materials. Twenty-two excel spreadsheets were created, each sheet containing twenty-two three digit numbers. The numbers were randomly generated with the constraint that at least half the numbers were odd. Each number subtended approximately 2.5° of visual angle. The twenty-two numbers were listed in a single column in each spreadsheet in a random order. This column was labeled as the "original" column; see Figure 1 for an example.

Twenty-two addition problems were also created, each containing five randomly generated digits ranging from 1-9. While participants performed the task eye track data were collected using the LC Technologies EyeGaze System operating at 60 Hz (16.7 samples/second).

Design. A within-subjects design was used. Half of the spreadsheets had no interruptions (control condition), and half of the spreadsheets had two interruptions each (interruption conditions). Each spreadsheet served as a trial. During the interruption trials two interruptions occurred – one during the first half of the trial and one during the second half of the trial. Each spreadsheet was randomly assigned as a control or interruption trial.

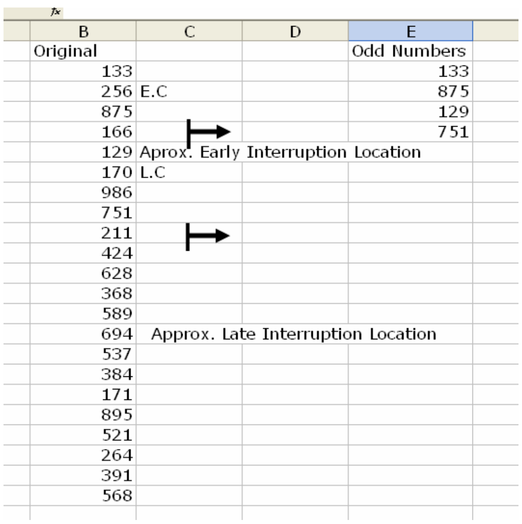


Figure 1. Screenshot of the odd numbers search task.

Procedure. The primary task required participants to type the odd numbers from the original column in the spreadsheet into a column labeled "odd numbers." They were instructed to begin at the top of the original column in the first spreadsheet and to type the odd numbers into the designated column without leaving spaces between the cells, as illustrated in Figure 1. Once they completed the spreadsheet they were to move on to the next spreadsheet, performing the same task until each spreadsheet had been completed.

The interrupting task was an instant message with an addition problem asking the subject to take the sum of 5 digits. When the instant message appeared, it completely occluded the spreadsheet and required immediate attention from the participant. The participant was instructed to attend to the instant message immediately and to mentally add the five digits as quickly and accurately as possible. Once the participant had the answer, they were instructed to type the answer in the message window, to send the message and then to close the instant message window. Once the instant message was sent, they were to resume the primary task. The total interruption time was approximately ten seconds. The interruptions occurred only after an entire 3 digit number was entered into the "odd numbers" column. An interruption never occurred while a number was being entered. After returning to the primary task, the odd numbers list remained on the spreadsheet. Thus, the odd numbers list served as a subtle environmental cue to participants. After looking at the last number entered in this column participants could look to the original numbers column and simply retrace there steps from that point.

The first two spreadsheets served as practice trials; one was a control trial, and one was an interruption trial. After successfully completing these two trials the participant began the experiment and completed all twenty trials at his/her own pace.

Measures. The reaction time data were analyzed by computing an inter-action interval for the control trials and the resumption lag for the interruption trials. The inter-action interval was the average time between entering odd numbers into the "odd numbers" column on the spreadsheet. The resumption lag was the average time from the end of the interrupting secondary task to the first action back on the primary task. The first action back on the primary task was always entering an odd number into the appropriate column. A resumption lag was calculated for the early interruptions and for the late interruptions.

The eye track data were analyzed using ProtoMatch, a software tool for analyzing eye track data (Myers & Schoelles, 2005). ProtoMatch defines fixations as a minimum of 6 samples within a default 2°-of-visual-angle window resolution. Each cell in the "original column" and "odd numbers" column was defined as an area of interest for categorizing the location of fixations.

Results and Discussion

Reaction Time Data

The inter-action interval and the mean resumption lags for the early and late interruptions were first examined to determine how disruptive the instant message interruptions were and whether there was a difference between early and late interruptions. These mean times, as illustrated in Figure 2, were compared using an analysis of variance (ANOVA). The omnibus ANOVA test was significant, $F(2, 20) = 51.5$, $p<.001$, MSE = .57. Tukey HSD post-hoc comparisons were used to determine which means were significantly different from each other. Both the early interruption point resumption lag ($M = 4.3$ sec) and the late interruption point resumption lag ($M = 4.1$ sec) were significantly longer than the inter-action interval ($M = 1.4$), $p<.01$. However, the early and late interruption point resumption lags were not significantly different from each other.

The significant differences between the resumption lags and the inter-action intervals demonstrated that the instant message interruptions were disruptive to performance on the primary task. However, the point of interruption (early vs. late) did not result in a significant difference in the resumption lags. The average location of the early interruption was approximately cell 6 in the spreadsheet and average location of the late interruption was approximately cell 15.

While the reaction time data indicated that the interruptions were disruptive, these data did not shed light on what specific processes were used to resume the primary task. In order to understand how participants resumed the primary task, we turned to the eye track data.

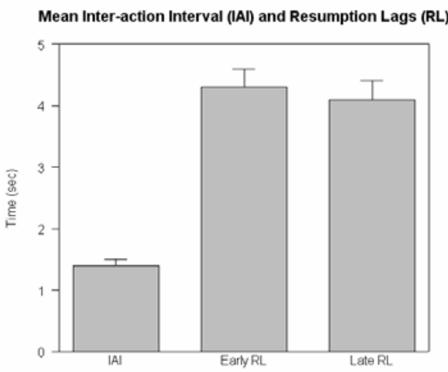


Figure 2. Mean inter-action interval and resumption lags.

Eye Track Data

In order to examine the specific processes used to resume the primary task at the perceptual level, three primary analyses were performed with the eye track data. First, the mean number of fixations during the inter-action interval and the early and late point resumption lags were examined. This analysis served as an indicator of how perceptually active participants were during the resumption lags as compared to the inter-action interval.

Second, the location of the first fixation back to the original column of the primary task during the resumption lag was compared for both the early and late interruptions. If participants started the task over again, the location of gazes should be similar in both cases. However, if participants used environmental cues or some kind of spatial heuristic, these locations should be very different. In addition, the fixation location was compared to the location of the environmental cues to determine whether a spatial heuristic was being used.

Third, a measure of where in the original column of the task the participant resumed as compared to where they left off prior to the interruption was performed. This analysis further examined the spatial heuristic view.

Number of Fixations. An ANOVA comparing the mean fixations during the inter-action interval and the early and late interruption point resumption lags was conducted, as illustrated in Figure 3. The omnibus ANOVA test was significant, F (2,20) = 57.84, *p*<.001, MSE = 3.18. Tukey HSD post-hoc comparisons were used to determine which means were significantly different from each other. The number of fixations during the early interruption point resumption lag (*M* = 8.6) was significantly greater than the number of fixations during the inter-action interval (*M* = 1.43), p<.01, as was the number of fixations during the late point interruption lag (*M* = 8.4), p<.01. The number of fixations during the early and late resumption lags was not significantly different from each other.

First these results showed that participants were perceptually active during the resumption lags as compared to the inter-action interval; there were approximately 8 fixations during the resumption lags as compared to approximately 2 during the inter-action intervals. In addition this analysis showed that participants were equally active during the resumption lags of both early and late interruptions in terms of the number of fixations.

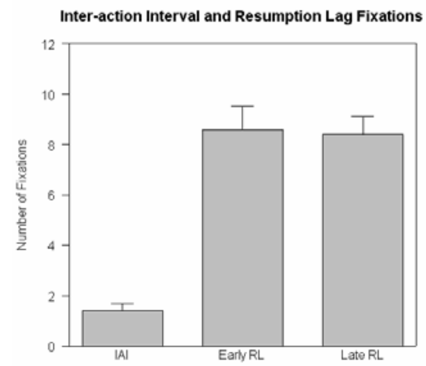


Figure 3. Mean fixations during the inter-action interval and the early and late resumption lags.

While this analysis showed that participants were not fixating at one location during the resumption lag, the pattern of fixations was not clear from this analysis alone. Participants may have retraced their steps from the beginning of the task, used an environmental cue upon resuming, or they may have used a spatial heuristic confining their fixations to one general area. In order to distinguish between these possibilities we examined the location of the initial fixation back to the original column after being interrupted.

Fixation Location. If participants started the task over their initial fixation back to the original column during the resumption lags should be to the beginning of the task for both early and late interruptions. The location of the initial fixation during the resumption lag was measured in terms of the cell in the original column that was fixated upon after returning to the primary task. For example, after the interruption, if the participant first fixated on the first number at the top of the original column, this location was marked as cell one. Thus, if participants started the task over, for both early and late interruption points, the average cell number should be around one.

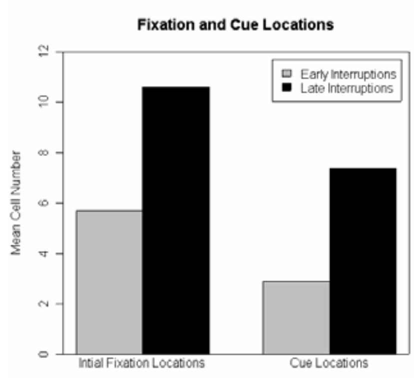
The mean initial fixation location to the odd numbers column during the resumption lags was compared for both early and late interruptions using an ANOVA. The early interruption fixation location (*M* = 5.7) was significantly different from the late interruption fixation location (*M* = 10.6), F (1, 10) = 248.3, *p*< .001, MSE = .52. Thus, participants did not fixate back to the same location after the early and late interruptions. There were a total of 22 cells in the original column. After the early interruption participants fixated towards the beginning of the task (i.e. near cell 6) and after the late interruptions participants fixated much further into the task (i.e. near cell 11). These data clearly show that participants did not start the task over after being interrupted. Figure 1 shows where the early and late interruptions took place and where participants initially fixated.

Did participants use environmental cues or did they use the spatial heuristic to resume the primary task? The difference in fixation locations for the early and late interruptions supports both of these views. The fixation location analysis presented above examined the initial fixation back to the original column. The very first fixation back to the primary task after the interruption was to the number that was just entered in the odd numbers column in 98% of the resumption lags. Thus, participants could have easily first fixated back to the odd numbers column to determine the last number they had entered and then they could have scanned directly across to the original column and searched or retraced their steps from that point. Thus, the numbers in the odd numbers column could have served as a subtle cue. The odd numbers list would be shorter for the early interruptions and longer for the late interruptions accounting for the difference in fixation locations.

If this was the case then the average position of the last number in the odd numbers list when an interruption was presented should be similar to the location of the initial fixation to the original list during the resumption lag. For example, during the early interruptions the analysis above showed that participant's initial fixation back to the original column was around cell 6. If participants were using the subtle cue then the average position of the last number in the odd numbers column for early interruptions should also be around cell 6. This should hold true for late interruptions as well, the last number in the odd numbers column should be around 10.

An ANOVA was used to compare the initial fixation location back to the original column during the resumption lags to the position of the last odd number that was entered in the odd numbers column; this was done for both early and late interruptions. As Figure 4 shows, there was a main effect of initial fixation location, $F(1, 10) = 45.9$, $p<.001$, $MSE = 2.2$. There was also a main effect for the location of the environmental cue, $F(1, 10) = 437.9$, $p<.001$, $MSE = .6$. The interaction between fixation location and cue location was not significant.

Figure 4. Initial fixation location and cue locations.



The fixation location analysis suggests that participants used some kind of spatial heuristic to remember the general area where they left off. During early interruptions they fixated back towards the beginning of the task during the resumption lag, and during late interruptions they fixated further into the task. Further, these locations were different from the positions of the cues. The early cue was approximately around cell 3 and the late cue was approximately around cell 7. Figure 1 shows where on the spreadsheet the interruptions occurred, where participants first fixated after resuming and where the early and late cues were. The arrows represent where participants initially fixated on the original column after resuming the task. The top arrow is the early interruption resumption point and the bottom arrow is the late interruption resumption point. The blocks at the beginning of the arrows represent the error bars. Finally, the E.C represents where the early cue cell was and the L.C represents where the late cue cell was. This figure shows that participants did not rely on the environmental cues to resume the task, rather they had some spatial awareness of where they were and they returned to this general area. Once participants returned to this general area how did they go about resuming the primary task? In order to answer this question we examined fixation distance.

Fixation Distance. While the initial fixation location analysis showed that participants used some kind of spatial heuristic, how close participant's initial fixation to the original column after the interruption was relative to where they fixated prior to the interruption is unknown. In order to answer this question, the distance between the last fixation on the primary task before the interruption and the first fixation back to the task after the interruption was computed.

The distance measure was computed in cell numbers, similar to the fixation location data. For this analysis the absolute value of the difference between the pre-interruption fixation and the initial post interruption fixation was taken. For example, if a participant was fixated on cell 8 just before being interrupted, and then returned to cell 6 after the interruption, the distance was computed as 2. A comparison distance was also computed for the control trials. In the control trials the distance was calculated based on the last fixation in service of searching for an odd number and the fixation to the actual odd number that was being entered into the "odd numbers" column. For example, if a participant is searching for an odd number and fixates on cell 6 and then on cell 8 where there is an odd number to be entered, the distance between these two cells was calculated as 2. In the control condition this measure is essentially the average fixation distance between entering odd numbers.

The mean fixation distances for the control trials and the early and late interruptions were compared using an ANOVA. The omnibus ANOVA test was significant, $F(2,20) = 92.08$, $p<.001$, $MSE = .53$. Tukey HSD post-hoc comparisons were used to determine which means were significantly different from each other. The mean distance from the control condition ($M = .57$) was significantly different from the early interruption distance ($M = 2.2$) $p<.01$, and the late interruption distance ($M = 4.7$) $p<.01$. In addition, the early and late interruption distances were significantly different from each other, $p<.01$.

The mean fixation distances in the interruption conditions were significantly greater than the mean fixation distance from the control condition. The greater fixation distance after the interruption shows that participants did not fixate right back where they left off. In the early interruption case, they were fixating approximately two cells away, and in the late fixation case, they fixated approximately six cells away. Thus, it appears that for the late interruptions, participants were less precise in returning to where they left off.

After participants initial fixation back to the original column, did they examine the numbers in a linear sequential fashion during the resumption lag in order to resume the primary task? The sequence of fixations during the resumption lags were examined and categorized as a linear sequential behavior or as some other type of behavior. This was done for fixations during the inter-action intervals and the early and late interruption lags. The number of times this behavior was exhibited was compared using an ANOVA. The omnibus ANOVA was significant, $F(2, 20) = 10.7$, $p<.01$, MSE = 417.9. Tukey HSD post-hoc comparisons were performed to examine which means were significantly different. The linear sequential behavior was exhibited during the inter-action interval (93% of the time) significantly more often than during the early interruption resumption lag (53%) and the late interruption resumption lag (71%), $p<.01$. There was no difference between the early and late resumption lags.

These analyses suggest that during the resumption lag participants were able to recall the general spatial location where they resumed. Following fixating in the general area, during early interruptions, over half of the time they sequentially fixated down the column of numbers. For late interruptions they sequentially fixated down the column of numbers over 70% of the time.

Finally, if there were process differences at the perceptual level for early and late interruption points, why weren't these differences seen in the resumption lag reaction time data? One explanation is that the duration of the fixations and saccades are so short that these differences are not reflected in the reaction time. The process differences at the perceptual level do not manifest themselves in the reaction times.

General Discussion

The eye movement data showed that participants were able to remember the general spatial location of where they were interrupted and were able to return to this general area when resuming the primary task. While participants may not be able to remember the specific location where they left off, they are able to remember the general spatial area where the interruption took place and subsequently where one should resume the task. This memory for spatial location needs to be included in the memory models of how interruptions are resumed. This spatial information seems to be more imprecise for the late interruptions based on the fixation distance data. This did not result in longer resumption lags for the late interruptions in this task possibly because of the nature of the task.

The duration of the interruption is an important feature to consider. In this task the length of the interruption was approximately 10 seconds. It is not clear what effects longer interruption durations would have on people's ability to remember where they were spatially. Just as the specific subgoal of the primary task decays (Altmann & Trafton, 2002) one's memory for the spatial location of where to resume may decay as well. Whether the spatial memory of where one last was decays just as readily as specific subgoal information needs further research.

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